Color-Magnitude Relationship of Type I Seyfert Galaxies Using Data From SDSS and GALEX

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Abstract

Data from the Sloan Digital Sky Survey (SDSS) and the Galaxy Evolution Explorer (GALEX) satellite were used to construct color-magnitude diagrams of Type I Seyfert galaxies with redshift values of 0.1<z<0.8. This study improved upon previous studies by having a much larger sample size (almost 1900 objects) and by increasing the covered wavelengths from 0.15 microns to 22 microns. Color was plotted against absolute magnitude in several bandwidths, from the far UV to the near infrared. High correlations were found in all wavelengths at certain z-values.

Introduction 1

Active galaxies are "active" due to the presence of supermassive black holes at their centers. While all galaxies harbor such black holes, in AGN the black holes are accreting large amounts of dust and gas. This in-falling material is heated to very high temperatures, emitting large amounts of energy across the entire electromagnetic spectrum.

The study of AGN provide benefits in several different areas–two areas, relevant to this project, are listed below:

- Black hole accretion is very efficient at converting matter into energy, making AGN some of the most luminous objects known[1].
- This high luminosity makes them visible from enormous distances (z≈7).

If the luminosity of an AGN is known, its distance can be calculated– it can then be used as a "standard candle" in order to help refine the distance scale of the universe.

While the term "AGN" encompasses several types of objects, this study focuses on Type I Seyfert galaxies. Seyfert galaxies are less luminous than quasars and have strong emission lines[2].

	Filter	Wavelength (μm)
GALEX	Far-UV	0.15
GALEX	Near-UV	0.23
SDSS	u	0.35
SDSS	g	0.48
SDSS	r	0.62
SDSS	i	0.76
SDSS	z	0.91
WISE	W2	4.6
WISE	W3	12

Figure 1. Several filter bands and instruments were used in this study.

Color Index	Correlation (r^2)
FUV-u	0.5950
FUV-g	0.6750
FUV-r	0.7584
FUV-I	0.7956
FUV-z	0.8072

Figure 2. The highest correlation was noted in the FUV-z band.

Methods 2

Those objects identified as Type I Seyfert galaxies were selected from the NED database. These specific targets were then cross-checked against objects imaged by GALEX and SDSS, giving 1886 objects which were observed by both.

The redshifts of these objects were used to calculate their distances. This allowed their absolute magnitudes to be determined using the distance-modulus equation.

Once the absolute and apparent magnitudes were known, color-magnitude diagrams were constructed using a variety of filter combinations (figure 1).

In each case, absolute magnitude used either GALEX Far-UV (FUV) or Near-UV (NUV) data. Color-index was determined by taking the FUV or NUV magnitudes and subtracting the brightness of each of the SDSS filters in turn. Those filter combinations which gave strong correlations ($r^2 > 0.7$) were singled out for further study (figure 2).

To eliminate the possibility that the high correlations were due to intervening dust absorbing UV from the Seyfert galaxy's accretion disk and then re-emitting that energy as infrared radiation, the two UV bands (FUV, NUV) were plotted against two WISE infrared bands (W2, W3). No correlation was shown to exist (figure 3).

The overall study looked at AGN located at redshifts of 0.1 < z < 0.8. Initially, the data were broken down into bins with z-values of 0.1. The highest correlations appeared at 0.4<z<0.5 so Seyferts at those redshifts were examined more closely.

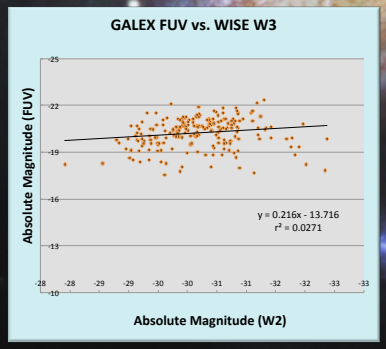

Figure 3. No correlation exists between the brightness of a Seyfert galaxy (Type I) in the UV and its brightness in the IR.

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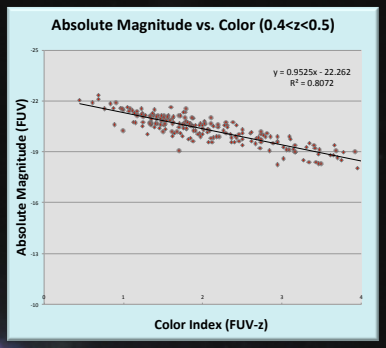


Figure 4. A strong correlation exists between the absolute magnitude of a Type I Seyfert galaxy and its color.

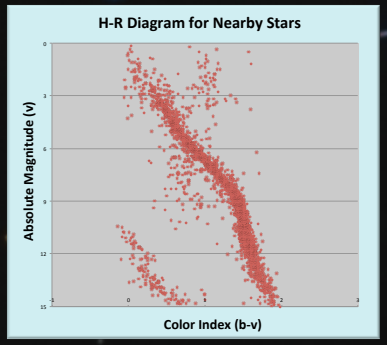


Figure 5. A color-magnitude diagram of nearby stars.

Results 3

High correlations were noted in several of the red-shift bins, particularly those where the filters used were furthest apart (NUV-z and FUV-z). Maximum correlations were found in the FUV vs. FUV-z. That region was selected for further investigation.

At first, questions were raised as to whether the high correlations shown in these filters were due to capturing the prominent emission lines of hydrogen (Lyman-alpha and hydrogen-alpha), but that was not the case (figure 6).

Although emission lines do occur in both the FUV and the z filters, these lines have their origins in different elements and are not directly correlated.

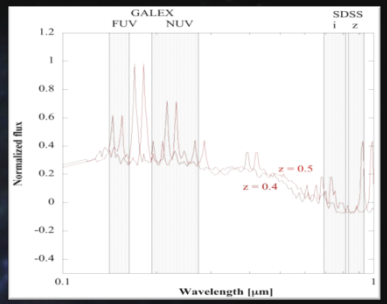
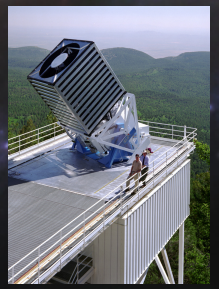
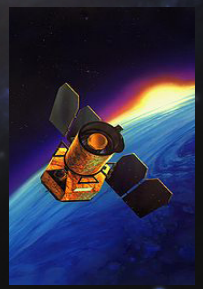


Figure 6. The locations of the emission lines relative to the filter bands varies with redshift[3].



The Sloan telescope (image: Rochester Institute of Technology



GALEX

Conclusion 4

The color of a Type I Seyfert galaxy is strongly correlated to its absolute magnitude. This relationship allows a color- magnitude graph, analogous to an H-R diagram, to be constructed.

Such a color-magnitude diagram will potentially provide a method, in addition to redshift, for determining the distances to these objects.

References

[1]http://www.ast.cam.ac.uk/research/x-ray.astrophysics/accretion

[2]http://ned.ipac.caltech.edu/level5/Glossary/Essay_seyfert.html

[3]The New Generation Atlas of Quasar Spectral Energy Distributions from Radio to X-rays, Shang et al, 2011 ApJS,196, 2.